What is claimed is:

1. A method of detecting a molecule of interest, the method comprising:
providing a first molecule covalently bonded to at least one magnetizable nanoparticle;
providing a second molecule covalently bonded to a substrate;
contacting the first molecule to the second molecule under conditions suitable for selective binding of the first molecule to the second molecule to form a complex; and
detecting the complex.

2. The method of claim 1, wherein the first molecule comprises a first nucleic acid molecule and the second molecule comprises a second nucleic acid molecule.

3. The method of claim 1, wherein the first molecule is DNA or RNA.

4. The method of claim 1, wherein the second molecule is DNA or RNA.

5. The method of claim 1, wherein the first molecule comprises a first protein molecule and the second molecule comprises a second protein molecule.

6. The method of claim 1, wherein the first molecule comprises a first peptide molecule and the second molecule comprises a second peptide molecule.

7. The method of claim 1, wherein the first molecule comprises an antigen molecule and the second molecule comprises an antibody molecule.

8. The method of claim 1, wherein the first molecule comprises an antibody molecule and the second molecule comprises an antigen molecule.

9. The method of claim 1, wherein the first molecule is covalently bonded to at least one magnetizable nanoparticle by a gold-thiol linkage.

10. The method of claim 1, wherein the nanoparticle is nonmagnetic in the absence of a magnetic field and is magnetic in the presence of a magnetic field.

11. The method of claim 1, wherein the nanoparticle is a paramagnetic particle, a superparamagnetic particle, or a synthetic ferrimagnetic particle.

12. The method of claim 1, wherein the nanoparticle comprises a noble metal surface layer.

13. The method of claim 1, wherein the nanoparticle comprises a gold surface layer.

14. The method of claim 1, wherein the nanoparticle has a mean diameter of about 5 nm to about 250 nm.

15. The method of claim 1, wherein the nanoparticle has a mean diameter of about 5 nm to about 20 nm.

16. The method of claim 1, wherein the substrate comprises a high sensitivity spin valve or a magnetic tunnel junction detector array.

17. The method of claim 1, wherein the detecting step comprises applying an external magnetic field gradient.

18. The method of claim 1, wherein the detecting step comprises applying a DC bias field and an AC tickling field.

19. The method of claim 1, wherein the detecting step comprises applying an external magnetic field gradient and detecting a net magnetic moment.

20. A spin valve detector array useful for the detection of magnetic nanoparticles, the detector array comprising a plurality of detection sites; wherein:

each of the plurality of detection sites comprise:

a first ferromagnetic layer;

a non-magnetic layer facially contacting the first ferromagnetic layer;

a second ferromagnetic layer facially contacting the non-magnetic layer;

a passivation layer facially contacting the second ferromagnetic layer; and

a binding molecule covalently bonded to the passivation layer; and

the binding molecule is selected from the group consisting of a nucleic acid, natural or synthetic DNA, natural or synthetic RNA, a peptide, a protein, an antibody, a lipid, a virus, a polymer, a toxin compound, a pharmaceutical compound, a biohazard compound, and an explosive compound.

21. The array of claim 20, wherein the first ferromagnetic layer comprises Co, Co alloys, Iron, Iron alloys, Fe-N, Fe_3O_4, Fe-Zr-Nb-B, Ni, Ni alloys, or mixtures thereof. This ferromagnetic layer is pinned by an exchange-bias layer or a synthetic ferromagnetic layer.

22. The array of claim 20, wherein the second ferromagnetic layer comprises Co, Co alloys, Iron, Iron alloys, Fe-N, Fe_3O_4, Fe-Zr-Nb-B, Ni, Ni alloys, or mixtures thereof.

23. The array of claim 20, wherein the passivation layer is about 1 nm to about 10 nm in thickness.

24. The array of claim 20, wherein the passivation layer comprises gold, tantalum, or glass. On the top of the passivation layer there may be an aperture to confine the DNA binding area.

25. The array of claim 20, wherein the non-magnetic layer comprises ruthenium, a ruthenium alloy, chromium, a chromium alloy, gold, a gold alloy, a noble metal, a noble metal alloy, or mixtures thereof.

26. The array of claim 20, further comprising a row decoder, a column decoder, a preamplifier, and at least one current source.

27. The array of claim 20, further comprising microfluidic circuits.

28. The array of claim 20, comprising a plurality of detection sites.

29. A magnetic tunnel junction (MTJ) detector array useful for the detection of magnetic nanoparticles, the detector array comprising a plurality of detection sites; wherein:

each of the plurality of detection sites comprise:

a bottom electrode;

a plurality of magnetic layers contacting the bottom electrode;

a tunnel barrier contacting at least one of the plurality of magnetic layers;

a ferromagnetic layer (the second magnetic layer) on the top of the tunnel barrier;

a gold layer contacting the second magnetic layer;

a conductive layer, typically with an aperture exposing part of the gold covered MTJ, contacting the gold layer; and

a binding molecule covalently bonded to the gold layer, and

the binding molecule is selected from the group consisting of a nucleic acid, natural or synthetic DNA, natural or synthetic RNA, a peptide, a protein, an antibody, a lipid, a virus, a polymer, a toxin compound, a

pharmaceutical compound, a biohazard compound, and an explosive compound.

30. The array of claim 29, wherein the conductive layer comprises aluminum, copper, palladium, platinum, ruthenium, silver, tin, titanium, alloys thereof, oxides thereof, and combinations thereof.

31. The array of claim 29, wherein the gold layer is from about 1 nm to about 10 nm in thickness.

32. The array of claim 29, wherein the binding molecule is covalently bonded to the gold layer by a gold-thiol covalent bond.

33. The array of claim 29, further comprising a row decoder, a column decoder, a preamplifier, and at least one current source.

34. The array of claim 29, further comprising microfluidic circuits.

35. The array of claim 29, comprising a plurality of detection sites.

36. The array of claim 29, having a magnetoresistance (MR) ratio, $\Delta R/R_0$, from about 10 % to about 50 %.

37. An antiferromagnetically coupled magnetic nanoparticle comprising two or more ferromagnetic layers and a covalently bonded target molecule, wherein:

the ferromagnetic layers comprise Fe_xCo_{1-x} (x is about 0.5 to about 0.7), Co, Co alloys, ferrite, Cobalt nitride, Cobalt oxide, Co-Pd, Co-Pt, Iron, Iron alloys, Fe-Au, Fe-Cr, Fe-N, Fe_3O_4, Fe-Pd, Fe-Pt, Fe-Zr-Nb-B, Mn-N, Nd-Fe-B, Nd-Fe-B-Nb-Cu, Ni, Ni alloys, or mixtures thereof; and

the target molecule is a nucleic acid, DNA, RNA, a peptide, a protein, an antibody, a lipid, a virus, a polymer, a toxin compound, a drug compound, a biohazard compound, or an explosive compound.

38. The nanoparticle of claim 37, wherein the ferromagnetic layers are separated by at least one nonmagnetic spacer layer.

39. The nanoparticle of claim 38, wherein the spacer layer comprises ruthenium, a ruthenium alloy, chromium, a chromium alloy, gold, a gold alloy, a noble metal, a noble metal alloy, or mixtures thereof.

40. The nanoparticle of claim 37, wherein the nanoparticle further comprises at least one paramagnetic layer.

41. The nanoparticle of claim 37, wherein the nanoparticle further comprises at least one superparamagnetic layer.

42. The nanoparticle of claim 37, wherein the nanoparticle is nonmagnetic in the absence of a magnetic field and is magnetic in the presence of a magnetic field.

43. The nanoparticle of claim 37, further comprising a gold surface layer or a glass surface layer.

44. The nanoparticle of claim 37, characterized as having a mean diameter of about 20 nm to about 250 nm.

45. The nanoparticle of claim 37, characterized as having a mean diameter of about 20 nm to about 50 nm.

46. A method of preparing an antiferromagnetically coupled magnetic nanoparticle conjugate, the method comprising:

providing an antiferromagnetically coupled magnetic nanoparticle comprising a gold surface layer or a glass surface layer;

providing a target molecule selected from the group consisting of a nucleic acid, DNA, RNA, a peptide, a protein, an antibody, a lipid, a virus, a polymer, a toxin compound, a pharmaceutical compound, a biohazard compound, and an explosive compound; and

contacting the nanoparticle and the target molecule under conditions suitable for the formation of a covalently bonded nanoparticle-target molecule conjugate.

47. The method of claim 46, wherein the conjugate is covalently bonded by a sulfur-gold covalent bond.